to certain trace elements especially molybdenum and boron in these soils has to be studied, for proper assessment of the factors, responsible for poor nodulation in groundnut.

REFERENCES

Bumpus, E. D. 1957. Legume Nodulation in Kenya Soils-1. *E. Afr. agric. J.*, 23 : 91.

Fred, E. B , I. L. Baldwin and E. McCoy. 1932. Root nodule bacteria of leguminous plants. Univ. Wisc. Studies on Science 5.

Masefield, G. B. 1958. Some fractors affecting nodulation in the tropics. Nutrition of legumes. Butterworths Scientific Publication, London.

Van Schrevan. 1958. Some factors affecting the uptake of nitrogen by legumes. Nutrition of legumes. Butterworths Scientific Publication, London.

---

https://doi.org/10.29321/MAJ.10.A03458

Sorghum Research Trends in the U. S. A.

by

S. B. P. RAO[1] and R. C. PICKETT[2]

Introduction : Unlike corn, sorghum is comparatively a new crop in the United States of America. It appears to have come in here sometime in the 1850's from the tropics of Africa and India. A few years ago, sorghum was reported as a "promising crop" here and today it is an important crop. In the 1930's, sorghum acreage and production was only 6 8 million acres and 93.7 million bushels respectively (Martin, 1936). As against this, in 1968 the U.S. produced 777 million bushels of grain sorghum; 4.3 million tons of forage and 10.3 million tons of silage, from a total acreage of 19.2 million acres (Anonymous, 1968).

The first seed of any kind of sorghum appears to have been brought to the U.S.A. in the slave ships of Africa. Broom corn was introduced during the 18th century from Europe; Johnson grass from Turkey in about 1930; sweet sorghum or sorgo from France in 1853; and sudan grass in 1909. By 1900 the U.S.A. had further introduced more than 1000 lots of sorghum from China, Manchuria, India and Africa. Today, different groups of sorghum are grown in the U.S. for distinct uses such as, grain mainly as feed grain for livestock; sorgos for forage or syrup; broom corn to make brooms; and sudan grass and sorghum-sudan hybrids exclusively for pasture or hay.

Summary of Past Work (1850 to 1950) : Barring a few, most of the sorghum introductions required some sort of selection or "taming" to adapt them to modern domestic agriculture. The first artificial grain sorghum crosses were made in 1914. The selection of desirable variations, hybrids, and mutations

---

1. and 2. Purdue University, Indiana (USA).

transformed the exotic sorghums into types well suited for growing them under a wide range of climate, soils and cultural practices. The greatest progress in sorghum improvement during the past 100 years has not been in increasing yields, but in developing varieties that can be machine harvested and varieties that are more palatable to livestock. The early maturing varieties like "Sooner Milo" *etc.* made it possible to extend the sorghum area into more northern latitudes, higher altitudes and drier sections. With the development of combine milo in the 1930's, sorghum replaced some of the wheat acreages in the southwest. Nearly 400 sorghum varieties, several of which are early maturing, were evolved and released for general cultivation during the last 100 years (*i.e.* from 1850 to 1950) (Ball, 1910; Martin, 1936; and Vivall *et al*, 1936).

Current Research (1950 to 1968): Many sorghum varieties formerly grown in the United States have now disappeared from the farms because of the sorghum hybrids coming into the picture. The desirability of F_1 hybrids of sorghum though long recognized, their utilization had to wait for the discovery of a usable male-sterile system. The cytoplasmic-genic-sterility developed by Stephens and Holland (1954) made the commercial production of hybrid sorghums an economic proposition. Hybrids in sorghum created a potential for expanded production. Hybrids also spurred research activity both in seed industries and in public agencies. Today, much sorghum research (both basic and applied) is now conducted by private industry in the United States. More emphasis is laid on items such as improved hybrids, inheritance studies, seed production, disease resistance, feeding value and milling properties of grain.

During the year just prior to, and after, the release of hybrids, the public agencies concentrated mainly on the development of new inbreds and hybrids. Some practical breeding is still being performed by federal and state employees, but there is a definite shift to more basic objectives in public institutions in the recent years. Increasing attention is given to the identification, development and release of lines having specific characteristics such as, disease resistance, dwarf stature, yellow endosperm, high protein and lysine lines, *etc.* These lines, as such, are released simply as sources of germplasm to the private breeders.

Prior to the 1960's, the amount of diversity in the sorghum collections in the U.S.A. had been small as compared to the total diversity existing in the sorghum species. A world collection of about 5,000 varieties was first grown in India in 1963-64 with the help of The Rockefeller Foundation under a 480 project. The seed of this collection is now in the hands of a number of public agencies and private seed companies in the U.S.A. The enormous

diversity found in this world collection is being employed in the plant breeding programs. Much of the diversity is limited in its direct use in this country because of day-length sensitivity and height problems associated with these exotic materials. The U.S. Department of Agriculture, and breeders at the Texas Agricultural Experiment Station are now engaged in converting a selected group of desirable exotic varieties to day-length insensitive, 4-dwarf forms. (Stephens *et al*, 1967). Similar conversion programs are also being handled by big seed companies like Pioneer, Northrupking and DeKalb. Varieties converted from tropical to temperate zone adaptation will be employed as breeding material in temperate zones. Breeders engaged in the conversion program hope to release inbred lines or parents for hybrid production suitable not only to the U.S. conditions, but also for all the sorghum growing areas in the world. The U.S.D.A. is planning to launch a scheme of an International project for testing of converted lines and new sorghum hybrids, in the near future.

So far, single crosses have been the standard hybrids in sorghum. Now, breeders at Kansas are attempting to release the three-way crosses, blends, and mixtures of steriles and fertiles. Sorghum testing programs for commercial hybrids were increased in size in the recent years. There is also good co-operation among the personnel in different states to obtain reliable data on multi-location tests. Improved testing procedures are being evaluated, with particular reference to border effects due to variations in height and maturity. Restricted randomization and wider plots have been suggested for critical tests. Sterility has been the subject of additional studies to see whether there are any additional nuclear-cytoplasmic systems in the world germplasm collection on hand.

Cytogenetic studies have been mainly concerned with reproductive characteristics, colchine effects, trisomics, and translocations. Ten primary trisomics in sorghum are now known and each of these 10 chromosomes has been identified in one or more translocations. The use of these stocks for critical analysis of specific loci appears to be the next logical step. The four maturity gene loci in sorghum and their allelic series have been studied and reported (Quinby, 1967). Interest in the genetic identity of varieties lies in the interaction of their alleles in different combinations. Twenty-eight varieties have now been identified for dominance or recessiveness at these four loci. Earliness found in the grain sorghum hybrids is considered to be a manifestation of hybrid vigor. But many sorghum-forage-bybrids have been found to be later in maturity than their parents. This has been attributed to the complementary action of maturity genes.

The philosophy of flowering process in sorghum is least understood. It is speculated that differences in concentration of gibberellin and auxin might

cause the differences in time of floral initiation among sorghum varieties. A concerted effort is now being made at Nebraska, in cooperation with The Rockefeller Foundation and the U.S.D.A., to obtain many answers to yield physiology in sorghum. Facets of this program encompass problems associated with the distribution of sorghum from very favorable climates conductive to high yields to marginal climates, where heat and drought stresses are the rule. Broadly, the investigations comprise of the interception and distribution of energy in the canopy and its utilization in the physiologic processes. More specifically, the influences of stand geometry, plant height, leaf architecture and inflorescence type, on light-distribution within the canopy, as they relate to yield are under study. Associated with light-distribution studies are experiments to evaluate such things as energy utilization or dissipation in CO_2 fixation; other syntheses; transport of metabolites; and transpiration. Aspects of mineral nutrition with general emphasis on N metabolism and protein synthesis are being studied. In this program, an attempt is being made to consider certain physiological processes either simultaneously or in a closely related manner to try and evaluate pertinent inter-relationships among some of the obvious yield factors. These types of studies are likely to permit deeper insight into the order of importance of different physiological processes and associated plant and environmental factors that influence yields, over the range of diverse climates in which sorghum is grown.

With the advent of the sorghum hybrids, the disease problems have become more serious than before. Anthracnose is observed to cause serious losses to sorghum in Georgia, downey mildew, Maize Dwarf Mosaic Virus (MDMV), and head smut in Texas, and nematodes in Mississippi. The MDMV disease in sorghum reached epiphytotic proportions in 1967 in Texas. This disease alone reduced yields by about 15% in 1967 and 10% in 1968. This virus also caused additional effects such as delayed maturity, stunting and reduced seed size. Texas studies have shown that some of the Feteritas and Hegaris possess MDMV tolerance. Inheritance study has indicated that MDMV tolerance is a dominant character in sorghum. Based on this information, sorghum hybrids tolerant to MDMV have been produced by the commercial breeders. The seeds of these hybrids appeared on U.S. markets in limited quantity only. Studies are in progress to find better and additional sources of resistance to this disease and for greater knowledge of genetics controlling inheritance of virus. Downey mildew is also gaining in importance in the recent years in the U.S. The most important aspect of this disease is the number of systematically infected seedlings in a field. The infected plants usually fail to survive or if they survive, they fail to head. Yield losses in incidents where 100% seedling infection occurred were absolute and complete and such instances are not unknown. (Frederiksen *et al*, 1967; 1969). Sources

of resistance have been found and resistance appears to be the best control of this disease. The existance of a new race of head smut, in a commercial field in Texas, has been substantiated and further work on this fungus is in progress (Frederiksen *et al*, 1965). The green bug (*Schizaphus graminum*) has become a serious threat to sorghum in the last two years. But effective chemical control measures have been found to check this pest.

The acreage of sorghum-sudan hybrids has increased rapidly in the U.S. since their introduction a decade ago. In some areas, these hybrids have replaced sudan grass and pearl millet for summer grazing, and in other areas, farmers grow them in preference to perennial grasses. In recent years, a great deal of research is being done with sorghum-sudan hybrids, because their high yields over a short-period of time are impressive. Though the digestible dry matter (DDM) of these hybrids are higher than warm season perennial grasses, their nutritive value in feeding trials has been limited by low voluntary intake by animals. Despite the higher HCN content reported in these hybrids, the problem of their toxicity has been less than anticipated. The feeding value of sorghum-sudan hybrids is rated as only 80% compared to corn silage and hence a concentrate supplement to make up this deficit has been suggested. Sorghum-sudan grass hybrids have found wide acceptance by U S. farmers, over a wide geographical area. However, some limitations of these hybrids are still apparent even after a decade of use. The potential of sorghum-sudan grass hybrids and the challenge they pose is acting as a stimulus for further intensified research in this field.

Sorghum for sugar and syrup production is still of much interest in some areas in the U.S. though the industry continues to decline on volume. Mississippi has chemical studies and a breeding program from which promising materials have been released recently. Georgia is also involved with the investigations of hybrids suitable for sorghum syrup production.

Studies on cultural practices have been intensified with the advent of hybrid sorghums in the U.S. In the past, little sorghum was fertilised. Application of fertilizer has increased since 1960 as a result of higher yield potential and expanded irrigation. Weed control by herbicides in sorghum needs special mention. An array of chemicals has been evolved. Though the overall results have been good, the lack of consistency in the performance of chemical weed killers is still a problem. Machinery and cultural practices used for other crops have been adopted or modified for use in growing sorghum. There are still many unresolved problems that are associated with planting of relatively small-sceded sorghum. In Georgia, work is in progress relating to harvesting efficiency to row-spacing of sorghum.

Grain sorghum is not a complete food for either man or beast, as it requires supplementing to make a balanced diet. Hence, work on grain quality improvement has been intensified in the recent years in the U.S. The Northern Utilization Laboratory of the U.S.D,A. is working on properties of sorghum starch, protein and oil. The Texas Experimental Station has started a cereal chemistry program. Sorghum milling companies have done considerable research in this field, but not all their information has been exchangeable. At Purdue University (Indiana), Pickett and his associates are engaged in studies pertaining to protein quantity and quality, under a USAID five-year-project. This is intended to serve sorghum improvement programs around the world, in addition to the information being of direct importance to the United States. Lines possessing high protein and high lysine have been identified. Many hybrids with protein and lysine content slightly higher than parents have been evolved. It is postulated that hybrids, with high protein and improved amino-acid composition, can be combined with high yield levels (up to 300 bu/A) in combine-height grain sorghum. Some of the taller, lodging resistant, sorghum-sudan grass hybrids are likely to create a big "boom" in sorghum development in this country. These possess twin advantages of superior yield and quality over corn which now holds the field.

Most cattle feeders who feed grain sorghum, process the grain by some method to improve its digestibility. Methods like steam-flaking, ensiling, pressure cooking, micronizing and popping improved feed efficiency. In the recent years, more attention is devoted to nutrition values and methods are being standardized to evaluate grain sorghum quality. In addition to running chemical tests, biological evaluations are made by actual feeding tests. The U.S.D.A. is planning to launch a project to evaluate selections from the world germplasm for nutritive quality. The "in vivo" nylon-bag-technique, for studying the digestibility of sorghum grain, has given encouraging results (Fogorid *et al*, 1966). Enzymatic digestion is another method that is now under critical study. This method lends well for screening large entries in the small-size samples, for energy value (Frederick *et al*, 1968). In short, more attention is now devoted to nutritional value in sorghum in the U. S. than ever before.

There is an excellent seed industry in the U. S. These seed companies are not more seed producers. They also conduct intensive research of high quality by employing eminent plant breeders and plant pathologists. It is interesting to record here that one single seed company (name is kept anonymous at the express wish of the management) had earmarked an annual budget of nearly $2 million for sorghum research and extension. Incidentally, this amount almost equals the total budgeted support of $2.17 million from Federal (55%) and State (45%) sources put together earmarked for the fiscal

year 1968-69 in the U. S. Methods to reduce outcrosses in seed blocks, improvements in production practices, methods to delay and/or reduce the time of bloom of inbreds are some of the important items of research pursued by seed companies now.

Summing up, it can be said that research findings from the public agencies have contributed largely to the development of a strong growing sorghum industry in the U.S. However, many still feel that the present rate of research out-put from the institutions (public and private) is not quite adequate to the demand in this growing industry. Sorghum, once considered as a crop of marginal lands, has now entered into a race with corn, and has come to occupy new niches in the corn belt already. With new developments in research and more high yielding and superior quality hybrids appearing on the U.S. market, the prospects of sorghum occupying an important place in this country are bright.

REFERENCES

Anon. 1968. U.S.D A. Statistical Reporting Service Cr. Pr. 2-3 (10-68) Crop Production· October 1968.

Ball, C. R. 1910. U.S.D.A. Plant Industries Bulletin 175.

Figroid, W.. W. H. Hale and B. Theurer. 1966. An evaluation of the nylon-bag technique for estimating rumen utilization of grains. J. Animal Sci., 25 : 592.

Frederiksen, R. A. 1969. The Progress of Downey Mildew, *Schlerospora sorghi* in the United States, an 8-year report. Paper presented at the Workshop on the Downey Mildew Diseases of Maize and Sorghum., 21-25 September 1969, U P. Agricultural University Partnagar, India.

Frederiksen, R. A. and D. T. Rosenow. 1967. Downey mildew of sorghum. Proc. Grain Sorghum Research and Utilization Conference. 5th Biennial meeting. (45-47).

Frederick, N. M., B. Theurer and W. N. Hale. 1968. Effect of moisture, heat and pressure on "in vitro" starch digestion of milo and barley. J. Animal Sci., 27 : 1110 (abstr.)

Frederiksen, R. A., D. T. Rosenow, L. Reyes and L. K. Edmunds. 1968. A new race of *sphacelotheca reiliana*. Plant Disease Reporter (in press).

Martin, John H. 1936. Sorghum Improvement. U.S.D.A. Yearbook 1936 : 523-560.

Quinby, John R. 1967. The Maturity Genes of Sorghum. Adv. Agron., 19 : 267-304.

———. 1968. Opportunities for Sorghum Improvement. Proc. 23rd Annual Corn and Sorghum Research Conference held in Chicago, Illinois. December 10-12, 1968, 170-76.

Stephens, J. C., F. R. Miller and D. T. Rosenow. 1967. Conversion of Alien Sorghums to early combine genotypes. Crop Sci., 7 : 306.

Vinall, H. N., J. C. Stephens and J. H. Martin. 1936. U.S.D.A. Tech. Bull., 506.